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INTER-LABORATORY COMPARISON OF SURFACE EMISSION RATE MEASUREMENTS OF WIDE AREA SOURCES

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Abstract. *The National Institute of Ionizing Radiation Metrology of ENEA (Italian National Agency for New Technologies, Energy and Sustainable Economic Development) (ENEA-INMRI) organized 7 national Inter-Laboratory Comparisons (ILC) on the measurement of the environmental radioactivity and of radionuclides of medical interest. In this paper, the ILC N°6, on surface contamination measurements, will be described. The objectives of this ILC were to test, at the national level, the participant capability of measuring the surface emission rate of two Wide Area Sources (WAS) of 241Am (alpha emitter) and of 90Sr (beta emitter). The reference values of the two surface emission rates were determined using the ENEA-INMRI Primary Standard, a windowless gas-flow proportional counter. The participants were asked to collect 10 readings of the emission for each of the two WAS. Each participant could use the most appropriate instrument and method, whose type, characteristics, and efficiency had to be communicated to ENEA-INMRI along with the values of the readings carried out under the same measurement conditions. From these data it was possible to check the consistency of the values of the surface emission rate determined by each participant, and their deviation from the reference values.*

1. Introduction

The correct measurement of the surface emission rate of alpha or beta radiation is necessary for the evaluation of the surface contamination by radioactive substances of materials and objects in multiple applications in the field of environmental surveillance, medical, industrial, nuclear applications, and scientific research. Surface contamination means the dispersion of radionuclides on any given surface by accident or intentionally.

To date, the National Institute of Ionizing Radiation Metrology (INMRI) of ENEA has satisfied numerous requests for calibration of superficial contamination monitors, coming from laboratories in the country that use these instruments for various needs. In this sense, the objectives of a national ILC in this sector were to evaluate the capability of all the laboratories to measure the surface emission rate of WAS and to guarantee for all of them the traceability at a national and international level to a common reference standard, developed and maintained at the INMRI. In this way it was possible to create, for the laboratories involved, the technical-scientific prerequisites to achieve adequate levels of accuracy and reliability in this measurement sector.

The emission rate level chosen falls within the range of interest for environmental monitoring techniques.

2. The measurand

The measurand object of the ILC6 is the surface emission rate from Wide Area Sources (WAS), in the solid angle of 2π sr, of both alpha and beta radiation emitted respectively by ^{241}Am and by ^{90}Sr/^{90}Y (pure beta emitter). The measurement is carried out, considering the indications given in the ISO 8769:2020 [1] and ISO 7503-1:2016 [2]. The WASs, whose uniformity of the activity distribution is better than 6%, were provided by INMRI. The experimental conditions selected for the ILC are shown in Table 1.

Table 1. Experimental conditions for the determination of the measurand (ILC 6).

Alpha-emitting radionuclide	^{241}Am
Beta-emitting radionuclide	^{90}Sr/^{90}Y
Measured particles	α, β^-
Source geometry	10 cm * 15 cm

3. Measurement methods and equipment

The Participant independently chose the instrument to perform the measurements required to determine the value of the measurand for each source covered by the ILC.

The actions carried out by the Participant according to the indications reported in the Information Note are the following:

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a. turn on, stabilization of the instrument and determination of the instrumental background;
b. acquisition of WAS readings using the Participant's instrument, respecting the experimental conditions;
c. recording of the readings and efficiency of the instrument used in the Results Sheet made available by INMRI on a web platform;
d. shipment of the two WASs to the next Participant.

Outside of the information note, the participant was asked to communicate the emission rate he calculated and its expanded uncertainty.

4. Traceability of the wide area sources

The WAS used for the ILC6 were characterized in terms of surface emission rate using an INMRI secondary standard of the same physical size, in turn traceable to the Italian primary standard validated through international comparisons with other Primary Metrological Institutes. In particular, the primary standard used is based on a proportional gas meter operating in 2π sr geometry (Figure 1). It can operate without any input window of the radiation field (windowless mode), thus carrying out absolute measurements of the WAS made of electrically conductive supports. This system complies with the ISO 7503-1:2016 [2] which provides the specifications of the α or β emitting WAS necessary to calibrate the instruments and therefore have traceable measurements.

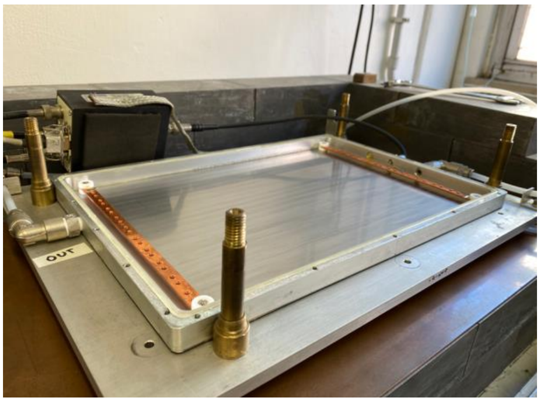

Figure 1. Proportional gas meter used by INMRI for the creation of the national primary standard of surface emission rate of the WAS.

5. Progress

The WAS were characterized in terms of surface emission rate (s-1), using a secondary standard of the INMRI, directly traceable to the primary standard, as already discussed in the previous paragraph.

The INMRI secondary standard is an Automess contamination meter (figure 2) made up of the dose rate meter 6150 AD 6/H [4] and the contamination probe 6150AD-k (sealed proportional counter [5]). It is connected to a stabilized voltage power supply and his calibration is periodically checked by WAS whose reference value of the emission rate is known and traceable.

Figure 2. Proportional gas meter used by INMRI for the creation of the national secondary standard of surface emission rate of the WAS.

Before being sent to the Participants, the two WAS were checked using the secondary standard. They were then sent to the Participants who had requested them via the registration web platform. Once the Participant had carried out the readings, in the conditions and ways illustrated in the information letter, he sent the two WAS to the next Participant until reaching the last Participant, who, after having read them, sent them back to the INMRI at the C.R. Casaccia ENEA, where they were checked again. As will be discussed in detail in the following paragraphs, the Participant communicated via the web platform the readings (cps) of the two sources and the efficiencies for the two radionuclides of the instrument used along with the associated uncertainties. Subsequently, the expanded uncertainty relating to the emission rate of the two sources was also requested. From these data, INMRI calculated the emission rate for each Participant and therefore determined:

- the percentage relative deviation (R)
- and the normalized error (E_n)

referred to the reference emission rate of the INMRI itself. Each Participant was associated with a confidential code so that they could view their result anonymously.

5. Analysis and presentation of the results

The analysis of the results was based on the comparison of the values provided by each Participant with the reference values provided by the INMRI.

The results of the comparison were analyzed in terms of statistical indicators commonly used in proficiency tests and interlaboratory comparisons [3].

In particular, the percentage relative deviation (R) was calculated as the percentage ratio of the difference between the values of the measurand M provided by the Participant and M_{rif} provided by the INMRI, to the INMRI value:

$$R = \frac{M - M_{rif}}{M_{rif}} \times 100 \quad (1)$$

The second statistical indicator is the normalized error or compatibility index (E_n), calculated as follows:

$$E_n = \frac{M - M_{rif}}{\sqrt{U^2 + U_{rif}^2 - 2U_{cp}^2}} \quad (2)$$

where U is the expanded uncertainty (coverage factor k=2) associated with the value of M as declared by the Participant, U_{rif} is the expanded uncertainty of M_{rif} estimated by INMRI and U_{cp} is the possible component of expanded uncertainty common to the Participant and the INMRI, as associated with the National Sample used as the origin of the traceability chain for the measurements or with other common data (e.g. nuclear data).

The values of the relative deviation and of the normalized error for each radionuclide are shown in tables 2, 3, 4 and 5.

Table 2. Relative differences between the surface emission rate value for ^{241}Am provided by the Participants and the INMRI reference value.

Participant Code	R (%)
ILC6-01	+32
ILC6-02	+8
ILC6-03	-3
ILC6-04	0
ILC6-05	+60
ILC6-06	+3
ILC6-07	+6
ILC6-08	-24
ILC6-09	+35
ILC6-10	+50
ILC6-11	+3
ILC6-12	-7
ILC6-13	-4
ILC6-14	+1
ILC6-15	Withdrawn
ILC6-16	+4
ILC6-17	Results not sent
ILC6-18	+27
ILC6-19	Withdrawn
ILC6-20	0
ILC6-21	Withdrawn
ILC6-22	-21
ILC6-23	+5
ILC6-24	Withdrawn
ILC6-25	-5
ILC6-26	Results not sent
ILC6-27	Withdrawn
ILC6-28	+35
ILC6-29	+12
ILC6-30	-1

Table 3. Normalized error E_n for ^{241}Am.

Participant Code	E_n
ILC6-01	Results not sent
ILC6-02	+0,27
ILC6-03	-0,142
ILC6-04	-0,003
ILC6-05	Results not sent
ILC6-06	Results not sent
ILC6-07	Results not sent
ILC6-08	-2,56
ILC6-09	Results not sent
ILC6-10	+6,044
ILC6-11	+0,379
ILC6-12	-1,00
ILC6-13	Results not sent
ILC6-14	Results not sent
ILC6-15	Withdrawn
ILC6-16	Results not sent
ILC6-17	Results not sent
ILC6-18	Results not sent
ILC6-19	Withdrawn
ILC6-20	Results not sent
ILC6-21	Withdrawn
ILC6-22	-2,22
ILC6-23	+0,46
ILC6-24	Withdrawn
ILC6-25	-0,72
ILC6-26	Results not sent
ILC6-27	Withdrawn
ILC6-28	+1,87
ILC6-29	Results not sent
ILC6-30	-0,18

Table 4. Relative differences between the surface emission rate value for ^{90}Sr provided by the Participants and the INMRI reference value.

Participant Code	R (%)
ILC6-01	+22
ILC6-02	+5
ILC6-03	+5
ILC6-04	+7
ILC6-05	+45
ILC6-06	-13
ILC6-07	+7
ILC6-08	+22
ILC6-09	-2
ILC6-10	0
ILC6-11	-2
ILC6-12	-13
ILC6-13	+4
ILC6-14	+3
ILC6-15	Withdrawn
ILC6-16	-12
ILC6-17	Results not sent
ILC6-18	+13
ILC6-19	Withdrawn
ILC6-20	+4
ILC6-21	Withdrawn
ILC6-22	+22
ILC6-23	+1
ILC6-24	Withdrawn
ILC6-25	+2
ILC6-26	Results not sent
ILC6-27	Withdrawn
ILC6-28	+36
ILC6-29	+12
ILC6-30	+6

Table 5. Normalized error E_n for ^{90}Sr.

Participant Code	E_n
ILC6-01	Results not sent
ILC6-02	+0,24
ILC6-03	+0,20
ILC6-04	+0,63
ILC6-05	Results not sent
ILC6-06	Results not sent
ILC6-07	Results not sent
ILC6-08	+1,54
ILC6-09	Results not sent
ILC6-10	-0,05
ILC6-11	-0,17
ILC6-12	-1,46
ILC6-13	Results not sent
ILC6-14	Results not sent
ILC6-15	Withdrawn
ILC6-16	Results not sent
ILC6-17	Results not sent
ILC6-18	Results not sent
ILC6-19	Withdrawn
ILC6-20	Results not sent
ILC6-21	Withdrawn
ILC6-22	+1,57
ILC6-23	+0,16
ILC6-24	Withdrawn
ILC6-25	+0,18
ILC6-26	Results not sent
ILC6-27	Withdrawn
ILC6-28	+2,20
ILC6-29	Results not sent
ILC6-30	+3,62

6. Conclusion

From a first analysis of the percentage values in these four tables, it becomes clear that, although half the Participants obtained R values less than 10 %, only the 28% of them were able to perform the ILC test with a reasonable uncertainty budget that sums up to a value of the expanded uncertainty that keeps the $|E_n| \leq 1$. In this sense, the picture obtained by this ILC is not satisfying considering also the regularity of the samples to be measured which were standard WAS. In order to try and clarify the difficulties of the laboratories, several bilateral meetings are being conducted to help the Participants, who do not satisfy the two criteria or did not send the expanded uncertainty, to assess their uncertainty budget and improve the metrological chain.

Table 6. Classification of the Participants for the relative differences R in percent for ^{241}Am.

Criteria	$\|R\| \leq 10$ %	$\|R\| \geq 10$ %	Result not sent
Outcome	In Agreement	Discrepant	Null
Number of participants	14	9	2
% of participants	56 %	36 %	8 %

Table 7. Classification of the Participants for the normalized error E_n for ^{241}Am.

Criteria	$\|E_n\| \leq 1$	$\|E_n\| > 1$	Result not sent
Outcome	In Agreement	Discrepant	Null
Number of participants	8	4	13
% of participants	32 %	16 %	52 %

As to the second radionuclide, ^{90}Sr, tables 8 and 9 report the values of R and E_n respectively. For this radionuclide only 7 Participants out of 25 comply with the two acceptance criteria.

Table 8. Classification of the Participants for the relative differences R in percent for ^{90}Sr.

Criteria	$\|R\| \leq 10\%$	$\|R\| \geq 10\%$	Result not sent
Outcome	In Agreement	Discrepant	Null
Number of participants	13	5	2
% of participants	52 %	40 %	8 %

Table 9. Classification of the Participants for the normalized error E_n for ^{90}Sr.

Criteria	$\| E_n \| \leq 1$	$\| E_n \| > 1$	Result not sent
Outcome	In Agreement	Discrepant	Null
Number of participants	7	5	13
% of participants	28 %	20 %	52 %

From a first analysis of the percentage values in these four tables, it becomes clear that, although half the Participants obtained R values less than 10 %, only the 28% of them were able to perform the ILC test with a reasonable uncertainty budget that sums up to a value of the expanded uncertainty that keeps the $|E_n| \leq 1$. In this sense, the picture obtained by this ILC is not satisfying considering also the regularity of the samples to be measured which were standard WAS. In order to try and clarify the difficulties of the laboratories, several bilateral meetings are being conducted to help the Participants, who do not satisfy the two criteria or did not send the expanded uncertainty, to assess their uncertainty budget and improve the metrological chain.

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